

Environmental Fate of Acephate

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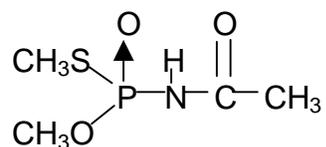
Summary

Acephate is hydrolyzed to the degradates DMPT and RE 17,245. Acephate does not undergo photolysis. Soil microorganisms rapidly degrade acephate under both aerobic and anaerobic conditions. The products of this are RE 18,420, methamidophos, and DMPT. Acephate's metabolites are very weakly adsorbed to the soil. They will be readily leached but will be quickly degraded in the soil. Acephate will not volatilize in any significant quantity to cause air contamination. Plants readily degrade acephate to methamidophos and DMPT. Acephate's rapid degradation makes it non-threatening to groundwater or surface water.

Physical and Chemical Properties

1. Common Name: Acephate (EPA, 1987)
2. Chemical name: O,S-dimethyl acetylphosphoramidothioate (EPA, 1987)
3. Trade Names: Orthene; Ortho 12420 (Merck, 1989)
4. CAS Registry No: 30560-19-1 (Merck, 1989)

5. Structural Formula:



(Chevron, 1972a)

6. Empirical Formula: C₄H₁₀NO₃PS (Merck, 1989)
7. Molecular Weight: 183.16 (Chevron, 1972a)
8. Density: 1.35 g/cm³ (Chevron, 1972a)

9. Solubility: water: 700 mg/mL
methylene chloride: 515 mg/mL
ethyl alcohol: 340 mg/mL
acetone: 151 mg/mL
ethyl acetate: 34.7 mg/mL
benzene: 15.7 mg/mL
toluene: 6.8 mg/mL
ether: 6.1 mg/mL
hexane: 0.1 mg/mL (Chevron, 1972a)
10. Vapor Pressure: 1.7×10^{-6} mmHg at 23 - 25°C (Chevron, 1972a)
11. Octanol/Water Partition, K_{OW} : 0.13 at 25°C (Chevron, 1972a)
12. Henry's Law Constant: $5.85 \times 10.13 \text{ atm m}^3 \text{ g-mol}^{-1}$ at 25°C (Chevron, 1972a)
13. Melting Point: 92 - 93 °C (Chevron, 1972a)
14. Types of Formulations: granular, pressurized liquid, soluble concentrates (both liquids and solids), and cartridge (EPA, 1987)

Environmental Fate

Hydrolysis

The hydrolysis rates of acephate were measured at various pH ranges. In the pH range of 5 to 7, the half-life is 50 days at 21°C and 20 days at 40°C. At pH 3 acephate's half-life is 65 days at 21°C. The half-life is 16 days at pH 9 and 21°C. These results show that acephate is more stable in acidic conditions and least stable in alkaline conditions (Chevron, 1972b).

The products of the hydrolysis of acephate were studied using ^{14}C -labeled acephate. This chemical was put in 0.25 N hydrochloric acid, phosphate buffer of pH 7 and 0.02 N sodium hydroxide at 40°C. In both the acid and base, acephate is hydrolyzed by cleavage of the P—N bond to O,S-dimethyl

phosphorothioate (DMPT). At pH 7, S-methyl acetylphosphoramidothioate (also known as (RE 17,245) is formed (Chevron, 1972c).

Szeto et al. measured the effect of pH on the acephate hydrolysis. For the pH range 4.0-6.9 there is no significant difference in hydrolysis rates at 20°C compared to 30°C. At pH 6.9, less than 20% of the initial acephate concentration is hydrolyzed in 20 days. At pH 8.2, the hydrolysis rate is affected by temperature. The remaining acephate concentration at 20°C was 77.9%, while at 30°C there was only 17.8% remaining (Szeto et al, 1979).

Photolysis

Acephate does not undergo photolysis. When acephate is in water or adsorbed onto glass or paper, it is stable to sunlight. Experiments have shown that acephate samples exposed to sunlight and those that are kept in the dark exhibit essentially the same degree of stability (Chevron, 1972d).

Soil Metabolism

Acephate is rapidly degraded in soil by microorganisms under both aerobic and anaerobic conditions. The half-life of acephate ranged from 0.5 to 3 days. The soil types in this experiment included loamy sand, sandy clay, silty clay loam, loam, and clay (Chevron, 1972e and 1972f). Acephate is readily metabolized in the soil under both aerobic and anaerobic conditions. The same products are formed in both of these conditions. The metabolites formed are O,S-dimethyl phosphoramidothioate (methamidophos) and O-methyl N-acetylphosphoramidate (RE 18,420) (Chevron, 1972g and #1972h).

According to EPA, 1987, acephate dissipates rapidly with half-lives of less than 3 and 6 days in aerobic and anaerobic soils, respectively. The major metabolite was found to be carbon dioxide in both types of soil. The leaching data included a soil thin-layer chromatography and a soil column study. The data indicates that acephate is mobile in most soils; however, aged acephate residues are immobile in sandy loam soil. Most of the applied acephate and the

degrade methamidophos degrade to immobile compounds in 20 days (EPA, 1987).

Field Dissipation

The leaching potential of acephate was studied by using ¹⁴C-labeled acephate. The chemical was applied to Oakley sandy loam at 2 ppm and incubated for 20 days. The treated soil was then placed on top of 12 inch columns of the same soil and leached with a ½ inch of water daily for 46 days. Leachates were analyzed for radioactivity. The analyses showed that 14 to 18% of the applied acephate remained in the treated soil after the 20-day incubation period (Chevron, 1972i).

Only 0.27% of the applied radioactivity was recovered in the leachates during the 46 days. Since acephate and its metabolite methamidophos are water-soluble and freely move in the soil, the findings indicate that neither chemical remained in significant quantities at the time leaching was initiated. Following the leaching, residual radioactivity was found to be almost entirely in the top 3 inches of the soil column. Only 1.1% of this was extractable with acetone during 2 hours in a soxhlet extractor. This method is known to remove acephate and methamidophos from the soil. This indicates that the residual ¹⁴C is neither of the two chemicals. It has probably been incorporated into the soil organic matter by soil microorganisms (Chevron, 1972i).

There was found to be no difference in the rate of acephate leaching in soil moistened to its field capacity or air-dried soil. In both cases, the acephate moves readily with water. Acephate and its soil metabolite, methamidophos are degraded three times faster in soil moistened to its field capacity than in air-dried soil (Chevron, 1972j).

Soil Adsorption

The adsorption coefficients of acephate, methamidophos, and DMPT were studied. The Freundlich soil adsorption/desorption coefficient (K_d) and the K_{OC} (adsorption on the basis of organic carbon) were determined in five soils. The

soils used were sand, sandy loam, clay loam, silty loam, and clay loam. The concentrations used were 0.1, 0.2, 0.5, and 1 µg/g dry weight soil. Acephate had a K_d of less than or equal to 0.090 and a K_{OC} less than or equal to 2.73. Methamidophos had a K_d less than or equal to 0.29 and a K_{OC} less than or equal to 0.88. DMPT's K_d was less than or equal to 0.30 with a K_{OC} less than or equal to 0.91. All three chemicals are very weakly adsorbed by soil. They will be readily leached, but they will not exist long because of their rapid degradation (Chevron, #63325).

Mobility

Soil:

A study was conducted to test the mobility of acephate in soil. Soil samples were sprayed with acephate at 9 lbs./acre and allowed to age, undisturbed except for watering for 21 weeks in a greenhouse. At the end of this period, the soil contained 0.05 ppm or less of acephate. There was no methamidophos detected. The amount of acephate found was about 0.5% of the applied dose. This remaining acephate was entirely leachable with the equivalent of 10 inches of rain. There was no bound acephate or methamidophos present in the soil (Chevron, #54161).

Water:

Hydrolysis of acephate is very slow, depending on pH and temperatures. It is faster at basic pH. Photodegradation does not occur with acephate. Acephate is very water soluble meaning it will move readily in soil with water. Despite this, the acephate is known to be rapidly degraded in the soil (Chevron, #54161).

Szeto et al studied the mobility of acephate in the water environment. This study's data shows that acephate will remain more in solution than partitioned into sediments. It was found that 20% of the applied acephate was in the bottom sediments after 2 days in a pond and 7 days in a creek. This is due to the high water solubility of acephate. This study also reported that acephate

could not be shown to escape from the water through volatilization because of its high water solubility (Szeto et al, 1979).

Air:

Acephate is not expected to contaminate the air and should not pose any vapor hazard to animals including humans. From the vapor pressure of the compound it was calculated that at ambient temperatures the concentration of acephate in saturated air would be 0.02 mg/m³ or 0.002 ppm. This is not a high enough concentration to produce any adverse effects on animals or the environment (Chevron, #54161).

Plant Metabolism

Acephate is readily degraded by plants. This is evident in studies done on both field sprayed crops and by using ¹⁴C-labeled acephate in the greenhouse. The half-life is approximately 5 to 10 days. Only about 5 to 10% of acephate degrades to methamidophos (O,S-dimethyl phosphoramidothioate). The rest of the acephate degrades to innocuous salts. No metabolites of toxicological concern have been observed or suspected, except for methamidophos. Possible degradation products of acephate and methamidophos are those in which the P—N, P—O, and/or P—S bonds are broken yielding P—OH acids. Conversion of any of these bonds to the P—OH group is sufficient to detoxify these compounds completely (Chevron, #54161).

Acephate is adsorbed onto leaf surfaces. Washing of the field treated broccoli, lettuce, and cotton leaves with water removed no more than 5% of the acephate residues. Translocation studies using ¹⁴C-labeled acephate show that there is only slight movement of chemical from the treated leaf to other parts of the plant, including roots and tubers. Field studies with potatoes and sugar beets have shown this (Chevron, #54161).

Fate in Mammals

¹⁴C-acephate studies were conducted on animals to determine what metabolites are formed when acephate enters the body. The urine of mammals was analyzed to determine that 75% was acephate. The remainder was made up of metabolites of acephate; 5% was DMPT and S-methyl acetyl phosphoramidothioate and 1% was methamidophos. There was no methamidophos found in the milk. In birds there was a small amount of methamidophos in feces and traces of it in the eggs. Acephate has been shown in vitro to be a weak inhibitor of acetylcholine esterase. Neither acephate nor its metabolite methamidophos bioconcentrates in any organism tested from simple organisms to mammals and birds. These two chemicals do not have any affect on soil microorganism populations or metabolic processes (Chevron, #54161).

Groundwater Monitoring

Acephate moves readily in soil with water giving it the potential to contaminate ground water. However, because of its rapid degradation in soil it is not expected that it would exist long enough in the soil to have enough time to move into the ground water (Chevron, #54161).

An experiment was conducted in Florida to determine acephate's potential to move into groundwater. This was done in extreme conditions where the rainfall was heavy and the soil was porous sand. Lettuce was sprayed several times with 1 lb./acre acephate. Three months later the same plot was treated at 3 lbs./acre (three times the recommended label rate). The amount of acephate in water at one foot varied from 0 to 2 ppm, with highest amount found on the 3 lb. Treatment 0 to 4 hours after application. The degradation product of acephate, methamidophos was only detected at a maximum of 0.06 ppm. Acephate was detected in the soil but at shallow depth, maximum occurring in the 6 to 12 inch sample. Traces of methamidophos were found in that sample also. No acephate or methamidophos was detected in any sample of water or soil at 2 ½ feet or deeper. This held true even after 7 treatments and 12 inches of rain (Chevron, #54161).

Yen, et al, using the behavior assessment model (BAM) and the groundwater potential model (GWP) assessed the contamination of groundwater by acephate and methamidophos. Acephate was found to have a longer half-life than methamidophos in soil; however, the mobility of methamidophos in both soils was slower than acephate. Acephate may lead to the contamination of groundwater much more easily than methamidophos under normal conditions (Yen, et al, 2000).

Surface Water Monitoring

Acephate is not intended for use directly in bodies of water (ponds or lakes). It could become a contaminant from runoff or accidental spills. An experiment was done to determine the acephate residues in water. Several ponds were treated with acephate at 0.1 ppm. Residues in the water decreased below 0.1 ppm within a week. The residue was undetectable in 6 weeks. There was no methamidophos detected. This concludes that even if a body of water was contaminated, within a short time no residues would remain either in the water or in the mud or vegetation (Chevron, #54161).

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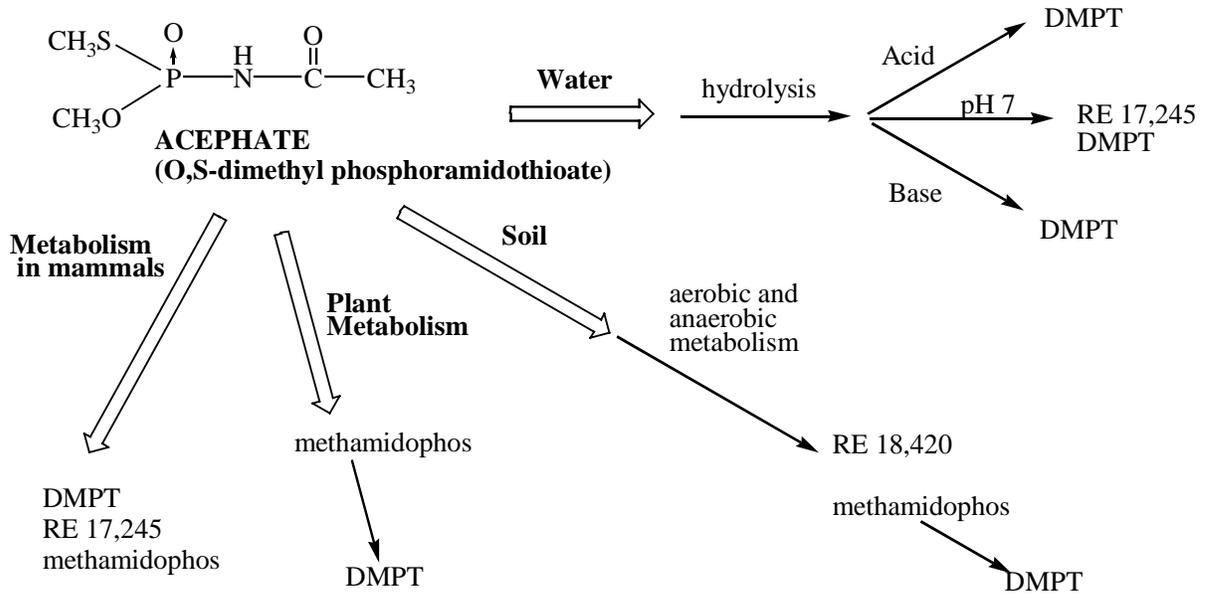
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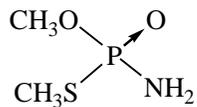
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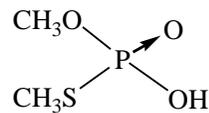
Degradation of Acephate



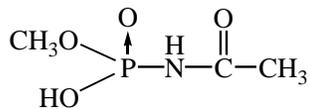
methamidophos
(O,S-dimethyl phosphoramidothioate)



DMPT
(O,S-dimethyl phosphorothioate)



RE 18,240
(O-methyl N-acetyl phosphoramidate)



RE 17,245
(S-methyl acetyl phosphoramidothioate)

